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## CONTENTS.

| | PAGE. |
|---|---|
| The Evolution of Safe and Accurate Fuse Protective Devices (Illustrated.) By Joseph Sachs, March 28, 1900 | 85 |
| Squier on An American Pacific Cable. Discussion December 27, 1899 | 117 |
| Notice of Paris Meeting | 129 |
| Obituary—Samuel Dana Greene | 130 |
| Advertisements | 135 |

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*A paper presented at the 121st Meeting of the American Institute of Electrical Engineers, New York, March 28th, 1900. Manager Steinmetz in the Chair.*

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# THE EVOLUTION OF SAFE AND ACCURATE FUSE PROTECTIVE DEVICES.

BY JOSEPH SACHS.

## Present Status of Fuses.

So much has been said and written of the shortcomings of the so-called safety fuse, that another discussion in this direction would certainly be but the raising of an old and well known ghost. Aside from voluminous other literature, the Transactions of this Institute record an ample array of investigations, tending to show the unreliable and far from satisfactory behavior of fuse metals, as commonly used under various conditions, and in many instances, indicating directions in which the action of such appliances may be greatly improved. Material improvement has been made in the blocks and bases for receiving these electro-thermal safety valves, but improvement in this direction partakes very much of the character of a quarantine instead of a prevention or cure for the disease. Notwithstanding the refinements and precautions adopted in the installation and use of these essential appliances, they are considered more a necessary evil than a safe and accurate protective device, whose addition to any electrical service would eliminate instead of, as in many instances add another danger element. In view therefore, of the universally poor reputation of fuse cut-out appliances and their failure to satisfactorily perform the service for which they are intended, the materialization of the promise held forth in the title of this paper may warrant a re-discussion of the fuse problem, with particular reference to the conditions and principles on which this much desired device is based and operates.

With the object of producing a protective device which could lay claim to safety and accuracy in fact and not in name only, the writer began a series of experiments several years ago. As a result of these experiments, a new form of fuse protective device has been developed which from extensive tests and various kinds of actual service has shown itself safe and accurate. This device is of the so-called enclosed fuse type which in several perfected forms has recently attained particular prominence, and which promises to be the cure-all of fuse difficulties.

FIG. 1.—Edison Fuse Plug.

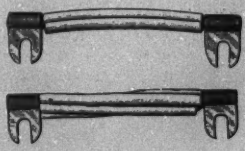


FIG. 3.—Soft Rubber Tube Fuses.

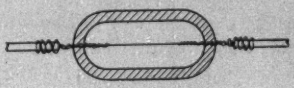


FIG. 2.—Edison Enclosed Fuse. Patent of May 4, 1880.

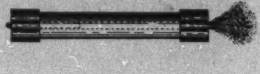


FIG. 4.—Fuse in Center of Close Fitting Insulating Cylinder.

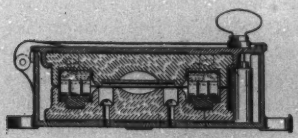


FIG. 5.—Fuse encased between two Insulating Blocks.

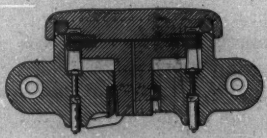


FIG. 6 —Fuse in Centrally Vented Holder.

Broadly speaking, the name "enclosed fuse" may be applied to any fuse-strip covered, encased or surrounded by a jacket, box or shell of some kind. Considered thus, probably the earliest device used in common practice fulfilling these conditions is the now famous Edison fuse plug, Fig. 1, whose tremendous success is unquestionably due to the facility with which it can be manipulated and the partial protection of the surroundings from the resulting effects of fuse disruption.

The value of such encasing of the fuse was fully appreciated even earlier than this, as is shown by a patent to Edison, Fig. 2, in 1880, which may be considered as the beginning of enclosed fuses. Fuses surrounded by abestos wrappings, close-fitting rubber tubes, threaded through and placed between blocks of insulating material, and placed in two-part blocks which formed practically a casing around the wire have followed. [See Figs. 3, 4, and 5]. For use on high potentials, a variety of fuse cut-outs have been used in which the fuse wire is placed in a hollow handle or holder of insulating material and equipped with terminal pieces to which the fuse wire is removably connected, and so constructed that the arc resulting from the blowing of the fuse is more or less destroyed by various mechanical arrangements or blown-out by the rush of the air in the handle to the exterior as shown in Fig. 6.

The name "enclosed" or "cartridge fuse" is, however, to-day particularly applied to fuses in which the fusible strip is placed inside of a tubular holding sheath or jacket which is filled with some yielding porous or similar insulating material through which the fuse wire is threaded, and which more or less fills the space between the wire and inside of the tube. The wire, tube and filling are made one complete self-contained device with suitable terminals at its ends. Such jacketed and insulated fuses possess peculiar features. The jacket if properly designed gives to the very deficient fuse the essential accuracy and safety aside from various other desirable additions.

At the present time enclosed or cartridge fuses may be divided into two distinct types, both of which embody the same general elements but differ in their disposition. In both, an enclosing tube entirely encases the fuse and a filling material of the character named, is placed in the tube around the wire. The difference in these two types simply consists in the composition and arrangement of the filling around the fuse. The simplest form is probably that in which the filling entirely surrounds the fuse wire and completely fills the interior of the tube. The other form involves the arrangement of the filling material around the wire so as to leave a portion of the fuse uncovered thereby, and surrounded by an air-chamber usually located about centrally in the tubular casing. Both of these types inherently possess great features of advantage over an exposed fuse wire. Their operation under various conditions of electrical service is, however,

generally governed by the same basic, electrical and thermal laws. The features inherent in each have received careful study and investigation, and this paper is intended to discuss the conditions governing the protection of electrical apparatus from excess current, the particular manner in which this new form of fuse protector fulfils these conditions, and the relative advantages of each of the two types.

## General Principles of Excess Current Protection.

An abnormal current existing in an electrical applicance tends to cause injury and damage due to heat, sparking, and mechanical and electrical strains and effects, either on the part of the electric apparatus itself or its driving or driven machinery. In the first two, the duration or time interval of the injurious effect enters into the resulting damage or injury as a direct function. The third effect may in some cases cause injurious results in so short a time interval that its action may be said to be almost instanteous under certain extreme conditions of abnormal current flow.

On all constant E. M. F. systems under normal conditions of operation, an abnormal current is due to a decreased impedance in the combined circuit acted on by the E. M. F. The two extremes of this abnormal condition are termed "overload" and "short-circuit." In both, the current flow is limited to the condition stated, but in the former the change in the normal condition of the circuit is slight as compared to the latter, when the circuit has been reduced to what may be said to be a minimum impedance. The interval in which these conditions cause injury with a certain normal current carrying capacity in the apparatus or circuit, may be quite an appreciable time in the case of the so-called over-load, or it may be so instantaneous that the time interval is inappreciable in the case of short-circuit, where the current assumes an enormous value with extreme rapidity. Altogether the question of injury from excess current may be simply stated as being dependent upon the abnormal energy impressed on the complete circuit or any particular portion thereof.

All electrical apparatus is intended to, or should carry a normal load current without any injurious effects indefinitely, and it will carry an excess current for a time interval depending inversely on the amount of excess above the normal current before sufficient energy has been transformed to produce injury. Slight

momentary rushes, or an excess current of short duration will not cause injury to the apparatus if the total energy developed is within the excess limit of the apparatus. Such changes in the current conditions occur, however, in a very large percentage of electrical apparatus and to open the circuit in these cases every time this occurs without taking cognizance of the time of its existence, is a fallacy unless governed by conditions other than the protection of the electrical apparatus from the abnormal current.

Since, however, the various elements of the complete circuit have a limitation in their current-carrying capacity, a short-circuit must be instantly checked, as such comparatively enormous current rush may apply sufficient energy to many times exceed the instantaneous overload capacity of any particular portion of the combined circuit. In current-producing and converting apparatus the sudden equivalent mechanical strains in the machine and its connected parts due to this effect are added to the heating strains. Not only is it, therefore, of the utmost importance to limit the maximum value of this enormous rush of current, but after the maximum has been reached and some part of the combined system gives way, an equally instantaneous drop of the current to 0, may under certain conditions cause results, which, although of another character are perhaps equally severe. The instantaneous removal of such excessive loads, taxes the governing applicances of the driving machinery, and also on inductive circuits taxes the insulation, due to the production of excessive potentials resulting from such breaking of the current.

For the protection, therefore, of the electrical apparatus alone without regard to other conditions which may affect its operation, an excess current protective device fulfils every condition if it possesses the following features:

1. A definite, unchangeable maximum continuous running current-carrying capacity.

2. A constant definite energy overload capacity depending inversely on the overload, and adjusted with the allowance of a reasonable safety factor for the apparatus to be protected. In this respect the protective device should be like the apparatus protected, uninjured by a excess of momentary or shorter duration than the time interval causing injury. In other words, it should simply be a device whose factor of safety is less than the device to be protected, but whose operation is based on the same gene-

ral principles. It must, therefore, operate practically instantaneously on short-circuit and in a time interval inversely dependent on the amount of ordinary overload.

3. Its operation should be safe under any condition of abnormal current at the voltage for which it is intended. No device can be universally safe in its self-contained form unless the arc and explosive effect coincident with the rupturing of the circuit under any condition is entirely suppressed. The device should not only prevent damage to extraneous surroundings but should be non-destructive to all connected parts other than those directly operative.

### Features of Thermal Cut-outs in Common Use.

Notwithstanding the many statements to the contrary, no similar electrical device is based on simpler, or even as simple operating principles as the thermal cut-out, as it may properly be called. The generation of heat in any current-carrying conductor is a well understood phenomenon. The rise of temperature in this conductor, due to the heat energy imparted to it, is governed by well-known conditions. If these conditions could be made fixed instead of constantly varying quantities, accuracy and certainty of action would result.

The heat energy imparted to a section of conductor by a certain current flowing for a definite time is a fixed quantity. The temperature attained in this conductor depends simply on how much of this heat energy is thrown from the conductor during that particular time interval. It is entirely obvious even without the various experimental investigations on this point, that any condition that varies the amount of heat energy taken from the conductor, varies the temperature attained, and hence the carrying-capacity of the conductor, since the melting of the metal is dependent thereon. The several ways in which this heat is dissipated from the ordinary air-exposed fuse conductor is entirely familiar to all electrical engineers but fuses always have been, and, are now, and in the case of open air fuses, probably always will be used indiscriminately without regard to these simple facts, and yet constancy and accuracy are expected.

Perhaps even more serious, however, than accuracy is the lack of safety in the ordinary exposed fuse. On this score a multitude of transgressions are heaped up against fuse devices of such types as have been in use a dozen years on nearly all classes

of high and low voltage services. No exposed fuse is safe (considered from the standpoint of fire hazard to its surroundings). The destructive and dangerous arcing of all exposed fuses when ruptured by excess current and particularly short-circuit conditions at the higher potential must be entirely and not partially eliminated before the fusible cut-out can be considered a perfectly satisfactory protective device. Even when a fire-proof housing is provided, safety is not absolutely assured. This serious objection to all open fuses is becoming more, rather than less serious in its aspects in view of the introduction of higher potentials and enormous generating capacities.

Aside from the shortcoming already stated, air surrounded fuses have other failings, prominently amongst which is the oxidation of the metal when subjected to heat, to which probably as much of the unreliability of such fuses may be attributed as to the conditions already stated. The formation of an enclosing envelope of oxide around the commonly used lead-tin alloy fuse wire is in many instances sufficient to hold the metal in a molten condition. The effect of such a condition is entirely obvious and well appreciated. The ease with which the cross-section of exposed fuses may be decreased by accident or otherwise ; the position of the fuse, whether vertical or horizontal, the straight or irregular arrangement of the strip between its terminals, and the contact between the fuse and circuit contacts: all have their effects on the carrying capacity and are deficiencies well understood and thoroughly appreciated. It is true that the use of a strip of fuse wire between terminals of better conducting metal would partially eliminate some of these bad features if an absolutely standard length between contact posts or screws were assured, but the loose practice of the past did not indicate any appreciation of the fact that any piece of porcelain having several brass stampings or castings mounted upon it is not necessarily a safe and accurate mounting for the simple yet delicate device whose exactness of operation can only be arrived at by definitely fixing all the conditions upon which its action depends.

Aside from the inherent deficiences of open fuse wires and links, the makers of such appliances are very much to blame for an absolutely loose and slipshod method of rating fuse wires and strips. The following matter is copied from three labels taken from spools of commercial fuse wire of different manufacturers. Such labels vary in indefiniteness from simply an omission of

the time of fusion to an omission of everything except so many amperes with the appended guarantee. It would certainly appear that this particular rating would be equally definite if the label simply informed the buyer that the wire he purchased was fuse wire. It certainly would have required less trouble in getting up the label and no more for the purchaser to discover whether 25 amperes was the blowing current, the maximum indefinite carrying capacity of the wire, or some other current that the wire would carry, and in what length and under what conditions it would carry this current. Lamps sold without any statement as to the voltage for which they are intended, almost corresponds to selling fuse wire by simply stating some current that it may or may not carry.

A.

CARRYING CAPACITY, 10 AMPERES.

Fusing point in open air at 70° 2 inch piece attached to Copper Terminals, 19 Amperes.

B.

DIAM. .127

This rating is based on fuse wires 1″ long with copper tips. Amperes 75.

C.

25 AMP.

Tested Fuse Wire Warranted.

There is no reason why this condition should have existed. Fuse wire can be rated as any other electrical device is rated at its maximum indefinite carrying capacity, although it may have been difficult to guarantee its use under conditions of rating.

Since the temperature attained in a conductor depends on the rate at which heat is received and thrown off, the fuse is essentially a time-interval device whose operation is based on the same principles that govern the injurious effect of the current on all other electrical apparatus.

Possessing inherently extreme structural simplicity, and involving an operative principle, not only due to the amount of current but also the time of its duration, the fusible cut-out need only have added to it elements that will standardize the varying conditions which now beset it in service, and effectively eliminate the injurious arcing. Not only can these desirable features be attained in the manner already mentioned, but by a proper selection of fuse metal and its environments, such devices can be constructed to entirely fulfil the three conditions given.

General Features and Description of Enclosed Fuses.

If the length of the fusible conductor is definitely fixed, the terminals properly proportioned so that the heat conduction from the fuse through them is correctly adjusted, and the fuse then protected from moving air currents and placed in an environment which cannot affect its action as to fusing, and which has a definite capacity for heat reception from the fusible strip, then some of the variable factors affecting the reliable action of the fusible conductor become fixed and the rise of temperature in the fusible strip for a certain current can be quite definitely relied upon.

Perhaps the very simplest arrangement embodying these elements compromises a definite length of insulating tubing entirely enclosing a fusible wire which is centrally fixed therein and surrounded throughout its length by the tube enclosed air as shown in Fig. 7. Such an arrangement fixes the length, terminals and environment, but it still gives us only an air surrounded wire with the disadvantages of air surrounded fuse wire and by no means produces a device which will operate on severe conditions of abnormal current flow without serious explosive effect. It is true that such fuses in very small ampere capacities, inside of two or three amperes, and at low voltages can be made to work successfully without explosion, but even then the tube must be strong if it is desired to withstand severe short-circuit without disagreeable external manifestations.

A casing might be constructed of sufficient strength, to withstand the pressure of the interior explosion and by a slight leakage arrangement allow the confined gases to gradually escape, but the practical limitation would soon be reached with fairly large current capacities at moderate or high service voltages. Various tests have amply demonstrated this.

By a very simple addition shown in Fig. 8 we can greatly improve the operation of the device as far as explosion and bursting of the tube is concerned. If the tube is entirely filled with some finely divided insulating material such as powdered chalk, the heat due to disruption of the fuse wire, instead of giving rise to an abnormal pressure in the enclosing tube by the heating and expansion of the enclosed air, will be largely taken up by the filling. The small remaining volume of air in expanding passes through the interstices of the filling and parts with more or less of its heat that would otherwise give rise to a destructive pressure. Larger capacity fuses will require firmly held end closures and vents somewhere in the enclosing shell, so that gases may escape from the tube. While the arcing of the enclosed fuse has been cured, the results due to the holding of the metal in a molten condition by the oxide film have been aggravated instead of relieved. The firmly packed filling around the wire serves as a

FIG. 7.—Air Filled Tube Fuse.

FIG. 8.—Chalk Filled Solid Packed Fuse.

secure bed for the melted metal and its oxide film, relieving it of all supporting strain and maintaining it in continuity although entirely in a molted condition.

The writer has made extensive experiments with this exact combination and amply demonstrated this seriously defective action. Fuses so constructed with lead-tin alloy and other wires would only disrupt the circuit when the wires attained a temperature apparently sufficient or almost so, to cause volatilization, heating the environment in some instances to a temperature which caused a burning and carbonization of the ordinary vulcanized fibre-tube which was used. This condition is maintained as long as the complete fuse is kept absolutely at rest, for any vibration, shaking or sudden movement of the fuse and block causes a disturbance of the fluid but firmly held wire and consequently a complete rupture or a decrease in its section at some point and consequent rupture at the current which it carried. The effect of a horizontal or vertical position of the fuse was examined, but it was found that the fuse would hold in a melted condition even

when placed vertically, if the filling was firmly placed around it. This action is due not so much to the firmly packed filling as it is to the strengthening of the oxide film by this closely surrounding material. As an example of actual operation the following record of a test made of a commercial fuse of this type is given.

### Record of Test of X Solid-Packed Fuse.

#### General Description of Fuse.

Grey fibre tube dia. ¼", length 2-¼" including brass ferrule caps at ends which served as contacts and to which tin-lead alloy fuse wire was directly soldered, extending from ferrule to ferrule centrally through a filling of white powder of chalky appearance and character. Fuse marked 6 and intended for 220-volt service. Not knowing what this rating was intended to imply, the fuse was started at 4 amperes and current increased.

| | | | | | |
|---|---|---|---|---|---|
| 4 | Amperes | for | 5 | minutes | Block in which fuse was supported well shaken after each interval. Tube hot. |
| 5 | " | " | 5 | " | |
| 6 | " | " | 20 | " | |
| 7 | " | " | 15 | " | At end of this time block given two quick raps and fuse opened. Tube abnormally hot. |

For all but short-circuit working, fuses so constructed are therefore defective since no accuracy of rating and blowing can be attained.

With the two above constructions well-known, the next step toward the production of a properly operative device is accomplished by simply effecting a combination between the air-filled tube and the tube filled with finely divided insulating material and by placing the fuse wire in the manner already described. As will be obvious from the illustration, this type of enclosed fuse obtains the advantages gained by a filling material around the fuse wire and also the advantages of a fuse suspended in an enclosed chamber of still air, a fixed environment, standard length and self-contained construction. It is, however, also true that the fuse-strip is affected by oxidation as any similar strip would be if surrounded by air. If such oxide coating should form and tend to affect the wire as already described, its action would be aided by the very short air space in some of these fuses and correspondingly short wire suspension. The rupture of the fuse strip under conditions of overload and short-circuit is initially similar to a rupture of a similar fuse entirely exposed in air. The heated and expanded air, enclosed in the air chamber and the gases resulting from the disrupted wire are forced into the interstices of the porous filling on each side of the air space and pass out, the arc

being destroyed by the rush of all air to the exterior without any re-supply, and thus partially blowing out the arc and partially killing it by its inability to maintain itself in an entirely carbonic oxide gas environment. Two designs based on these lines have thus far been commercially developed in this country, and a similar construction has been exploited in England. Sectional views of the two American designs are shown in Figs. 9, 10, and 11, These drawings are self-explanatory.

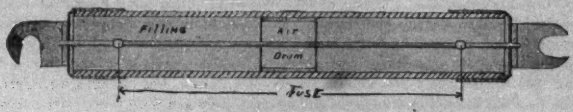



FIG. 9.—Central Air Space and Loose Finely Divided End Filling Fuse (Single Wire).

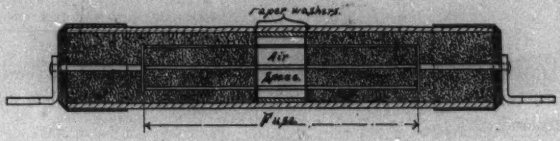
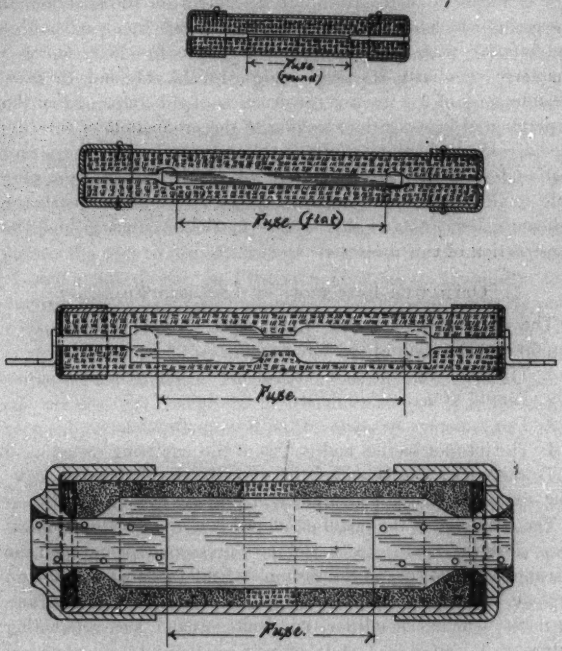



FIG. 10.—Central Air Space Fuse. Multiple Wires and Loose Finely Divided End Filling.

FIG. 11.—Air Space and Asbestos Plugged Fuse.

The design shown in Figs. 9 and 10 has unquestionably accomplished most excellent results in a very large number of installations and in various current capacities and even at very high voltages. The modifications in the fuse strip construction showing the use of single and multiple wires between the terminals is to be noted. By the use of such multiple wires a smaller aggregate area of metal is necessary than when one single wire is used. It may generally be stated that the operation of this type may be varied by a variation in air space length and area aside from other conditions which will be more fully discussed later.

Owing to the absence of vents in the end caps and the slight porosity of the tube filling material in Fig. 11, which is abestos paper rolled around the fuse wire instead of a loose finely divided powder material as used in Figs. 9 and 10, the former design judged from tests made by the writer appears to be of doubtful utility under very severe conditions and particularly if in very large sizes.




FIGS. 12, 13, 14, 15.—Solid Packed Fuses.

The writer's original conception of a non-arcing accurate fuse was to combine with the fusible strip an environment suitably held around the wire and intended to effect a combining action between the wire and heated fuse metal, so that not only would the holding in a molten condition be overcome but the combining of the environment with the oxides of the disrupted fuse

would kill the arc. This principle has been the basis of development in the investigations taken up in this direction by the writer. The results as at present perfected show a fuse protector whose general construction is of the solid packed no-air-chamber type, but in which a molten hanging of the wire is impossible and in which the explosive tendency is reduced to a minimum, and all flashing and arcing entirely eliminated. This fuse is furnished with an indicating device on the exterior of the casing which at all times positively shows the condition of the interior wire and the rupturing of the fuse wire is of a character peculiarly its own. Figs. 12, 13, 14, and 15 show modifications of the interior construction of this fuse. From the experimental investigations leading to the production of this device various deductions relative to the proper design of such protective devices have resulted, many of which are equally applicable to all fuses. A discussion of these is combined with the following description of the various elements entering into the construction of this protective applicance.

### Operative Principles of Enclosed Fuses.

The satisfactory operation of an enclosed fuse is based on a careful consideration of the following:

1. The character, size and form of the fusible strip.
2. Length of active fusible strip.
3. The character and mass of the fuse environment.
4. The interior section and length of the enclosing casing.

To these may also be added the necessity for indication, compact size and facility of manipulation and low cost.

The character of the metal employed is of the greatest importance, since the heated gases and pressures consequent upon the disruption of the fuse in the casing, and the tendency to arc and explode, is governed by the mass of metal to be disrupted at any particular current condition and voltage, and the conducting nature of its vapors. A metal of high conductivity, whose vapors rapidly and readily change their conducting nature, and which has a fairly high melting temperature, fulfils this requirement. In the matter of conductivity, there is no limit, but the character of the wire environment restricts the raising of the temperature to a point beyond which the casing is injured, and which may be objectionable from other causes. A metal having the current conducting properties of copper would constitute an ideal

fuse metal for enclosed fuses. Copper wire, however, is not desirable, in view of the temperature limitation, and the fact that this metal when disrupted results in a vapor which seems to be of the most highly conducting nature, feeding the arc and causing it to hold and burn back on the terminals with a tenacity exceeding that resulting from almost any other metal which the writer has experimented with. This peculiarity of copper vapor is amply demonstrated by the deposition of a film of metallic copper on the ordinary types of fuse blocks, due to the arc attacking the copper terminals of the fuse links. Experience with various metal alloys containing copper seems to give similar results. On 500-volt D. C. circuits, under severe conditions of short-circuit, with fairly large exposed copper fuse wire, the roaring, holding and flashing of the arc is certainly sufficient to prohibit the use of open copper fuses where such abnormal current conditions are possible on these higher voltage circuits.

The commonly used lead-tin alloy fuse metals by no means possess the desired characteristics. It is true that fuses composed of such metals do not, on disruption, give rise to as highly conducting vapors, as copper; but owing to their comparatively poor conductivity and low melting point, they essentially must embody a large mass of metal in any fuse of given length, due to the ample section required. The severe oxidation of such fuse alloys and the possible change in molecular structure of alloys of this type subjected to repeated heating and cooling must not be overlooked.

The search for a satisfactory fuse metal seems now to be directed toward such metals as aluminium, cadmium, tin, zinc and those of a similar nature, or their alloys. A simple metal is however, more desirable for this purpose, unless the alloy possesses features which cannot be obtained otherwise. Since the desired metal must be cheap, aluminium and zinc at once become most attractive. Both possess the desired conductivity, and melting point and their vapors have the desired high-resistance property which is, no doubt, due to their extremely rapid oxidation. The mass of metal used in fuse wires of either of these is therefore small, and the opening of the arc is readily accomplished. These two metals have up to date been generally adopted in the writer's various forms of fuse devices, but it is still desired to further advance in the direction noted. Since the carrying capacity of the wire depends upon its ability to throw off more or

less of the heat generated therein, it necessarily follows that a single round sectioned wire does not attain the desired goal in regard to the use of a minimum mass of metal. The simplest solution is to flatten the fuse strip and thus raise its heat throwing-off ability to a maximum. Another method is to construct a fuse strip of a multiplicity of wires. The first method is used by the writer in all larger fuses exclusively, and performs another function which greatly adds to the operation of the enclosed fuse and permits the use of smaller tube sections. In order to effect a thorough and rapid commingling of the ruptured wire and filling material, it is essential to bring the maximum metal surface in contact with the filling, which is very well attained by the use of a flat strip.

In fuses intended to work on the various commercial voltages it has been the practice to vary the length of the fuse strip in proportion to the voltage. Owing to the decreased carrying capacity of any particular fuse wire section due to increased length, it is highly advisable to reduce the latter to a minimum, consistent with satisfactory working.

Open or enclosed fuses of ample length when subjected to gradual overloads, in which the temperature rise in the metal is dependent on an appreciable time interval will, if of even section and with an even surrounding environment and similarly connected at each end, attain the maximum temperature at a point central between the ends. The length of the rupture, under such conditions, depends on the ability of the arc started at the initial break in the metallic continuity to consume the metal on each side of the break. With any particular metal this maximum arcing length will depend on the E. M. F. sustaining the arc and its environment. In air this is much longer than in a casing and filling, arranged so as to exclude as much air as possible, and dissipate the conducting vapors of the disrupted fuse metal. For any particular voltage the length of arcing distance obviously depends on the conducting character of the vapors. If, however, the disrupting current is extremely large, as in the case of an enormous overload or short-circuit, then the heating of the complete metal strip is so instantaneous that a melting temperature is attained over its entire length, and it is completely disrupted. An arc will then only result if the distance between the contact terminal pieces on the base block are inside of the arcing distance for that particular metal and voltage,

By an adjustment of fuse-length to meet this condition it is possible to operate an open fuse at any voltage without any arc under short-circuit conditions, but by no means does this in any way affect the resulting arc on slow overload melting of the metal. The length necessary for such non-arcing short-circuit operation will be found excessive in practice. Since the slow overload arcing is retained, and even though disrupted without arc, the short-circuit operation necessarily entails the throwing off of a quantity of molten metal, but very slight additional safety is afforded to the surroundings, although the contacts and other parts of the base block are protected. The enclosing of the fuse wire in a casing properly filled and held around the wire greatly shortens the maximum arcing distance under over-load or short-circuit.

The varying severity of short-circuit effects at different parts of the conducting system with large and small generating capacity and with varying conditions of output and character of service, are frequently ignored in considering the operation of protective applicances of this nature. With heavy current capacity protective devices a very small retarding medium greatly affects the operation of the protective device. Short-circuits and heavy over-load ruptures, on large over-compounded and low-power factor systems are instances of particularly severe service.

It, is, however, only necessary for a protective device such as a fuse to accomplish satisfactory results on the particular service in connection with which it is used. While it is entirely possible to provide a device capable of meeting the most extreme condition, such ability, if entailing additional cost, is unnecessary where the extreme conditions are impossible. The peculiar result obtained in a recent test made by short circuiting two of these solid packed fuses on a 2500-volt line and two exactly similar fuses on a 500-volt line, will illustrate the fact that the voltage does not necessarily determine the severity of the short-circuiting effect on a fuse of ample dimensions.

COMPARATIVE SHORT-CIRCUIT TEST OF LONG FUSE ON 2500 VOLT A. C. AND 500 VOLT D. C.

18" long, 1" diameter fibre tube. Filled solid active powder.
12" flat fuse strip. Capacity 20 amps. continuously.
A. C. 2500 volts on heavy feeder about 1 mile from station, lightly loaded. Two fuses as above, each thrown singly across line. Opening of fuse tubes after test disclosed about 5 to 5½" of undestroyed strip in each tube. This remaining length was made up of several pieces. The length of strip destroyed under this condition was from 6½ to 7"

D. C. 500 volts on 0000 feeder about 1¼ miles from station. Owing to load variation, test was made only when voltmeter indicated 500 volts. Two fuses as above. Each thrown singly across line. Openings of tubes disclosed a disruption of the entire fuse strip between terminals with the exception of ¼" in one and 1½" in the other.

Similar tests with somewhat longer fuses on 6000 volts show the following results:

SHORT-CIRCUIT TEST OF 5,000 TO 10,000 VOLT FUSES.

S. K. C. Inductor, two phase generator belted to water-wheel. Gates well open. No load on generator except test. Voltage measured 6000. Fuses thrown across short heavy leads connected to one side and allowed to remain connected for some time after operating. Two-phase capacity of generator. 300 K W.

24" long 1" diameter fibre tube. Filled solid active powder.
15" flat fuse strip. Capacity 20 amps.

Two fuses as above tested. Each connected in series with larger capacity fuse and thrown across generator. In both cases the 20 amp. fuse only opened. Opening of tube disclosed a disruption of all except one or two very short pieces of the strip.

The very much shorter disruption on the 2500-volt circuit is noteworthy. It may be due to the inability of the 2500-volt A. C. arc to maintain itself over a greater distance, and also to the lagging of the current rush so that at the instant of rupture the total heat energy acting on the fuse strip was insufficient to totally destroy the entire mass of metal. This experiment is apparently contrary to the generally accepted ideas governing the length and adjustment of fuses of this type. In practice the actual lengths of the fuse strips are very much shorter than those tested on 2500 and 500 volts.

The average lengths as used in these solid packed fuses, are approximately:

| | |
|---|---|
| 220 volts, | 1¼" |
| 500 volts, | 3" |
| 2500 volts, | 4" |
| 3000 to 10,000 volts, | 6" to 18" |

This is the distance between terminal wires inside and has no particular bearing on the casing, which varies.

The use of inductances in series with large fuses to choke heavy current rushes and thus ease the blow on short-circuit, has been suggested. Recent tests with 600-ampere fuses on a very heavy feeder at a short distance from one of the largest 500-volt direct connected railway stations, has somewhat lowered the writer's

opinion of this buffing device. One of these fuses tested without the inductance and thrown directly as a short-circuit across the feeders worked in a far superior manner to another having an inductance of about twelve turns in series with it and similarly treated. Indications seemed to warrant the conclusion that while the inductance may have choked the maximum rush; it, however, increased the potential of break across the fuse terminals.

Another important feature dependent upon the length of fuse, its consequent resistance and amount of energy dissipated therein, is the temperature attained by the surface of the tube casing. This depends upon the amount of heat energy delivered from the fuse to the environment and consequently upon the amount of energy dissipated in the fuse for any patricular current. A simple arrangement of the strip section, small in the center and increasing toward the terminal wires, accomplishes most excellent results in this direction. Fuses so constructed have a far lower tube surface temperature than when an even strip is employed, although more metal must necessarily be dissipated.

From prior deductions it has appeared that a satisfactory action of the tube-surrounded fuse strip can only be attained by reducing the amount of confined air to a minimum, and by providing a means for effecting a maximum cooling effect on the heated and expanding gases. The closest attainment of this result is obviously in a solid filled tube. Irrespective, however, of the particular quantity of filling in the tube, its presence in contact with the wire, necessarily affects the action of the latter. This environment, no matter what its arrangement, has a certain heat conductivity and capacity. It carries heat away from the conductor more rapidly when cold, than after it and the conductor have obtained a higher temperature. The mass of this material around the wire affects the time required to attain a certain temperature in the wire, and the heat conductivity of the material employed as an environment to the wire will affect its carrying capacity. A proper relationship must, therefore, exist between the wire and the environment, in order that the complete device has a minimum difference in the time necessary to attain an operative temperature in the fuse-strip when first put in circuit, or after it has endured its full current capacity for some time. It is certainly assumed that the filling satisfactorily fulfils its essential function as an arc dissipator, and that the fuse has been properly located therein.

The desired result as to so-called hot and cold blowing of the fuse device is accomplished by reducing the mass of environment to a minimum. It is obvious that with a certain fixed heat throwing-off capacity in the wire, the current carrying capacity of the latter will depend upon the rate of heat conduction to, and dissipation by radiation from the tube surface, and by conduction longitudinally through the terminal wire and environment to the contact posts. The heat conductivity of the environment therefore governs the carrying capacity of the complete device, but this function is decreased if insufficient environment section is provided, so that the radiation and conduction therefrom, owing to lack of tube surface, is not in the proper proportion to the amount of heat thrown-off by the conductor. The exterior surface temperature of the tube, other conditions being fixed, is certainly dependent upon the surface area. Decreased surface temperature can therefore be obtained by increased surface area,

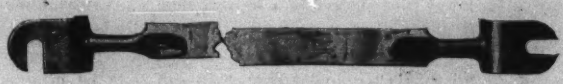


FIG. 16.—Strip Ruptured at Low Arcless Voltage in an Environment of Active and Inert Material. Note Rupture at one end of Fuse Strip where Active Material was Located and Melted Condition of Center.

but this necessarily entails increased mass which is not desirable, for reasons already given. For similar reasons it is desirable to minimize the heat conduction from the fuse to the contacts, through small terminal wires.

By a careful adjustment of the various parts the writer has obtained comparatively low surface temperature, minimum ratio of hot to cold blowing time and practically very little or no difference in the current carrying capacity of the fuse strip, from that which it has when entirely surrounded by an air environment.

To produce the desired result relative to the prevention of any holding of the wire in a molten condition, a very careful experimental investigation was undertaken. Based on the original conception, a combination of elements has been developed which not only combine under heat action of the current, but in which the character of all or a portion of the environment is such that the retention of the wire continuity after melting

temperature has been reached is impossible. This result is accomplished by the use of a material around the wire which readily fluxes with the metallic oxides at the temperature of the molten metal. Various substances are available for this purpose, but the writer has found mixtures in the form of loose, finely divided powders, in which borax is included as an element most desirable. With the metal employed in the fuse strip, this environment produces most peculiar results, causing a fluxing only upon the attainment of the temperature reached by the wire in its molten overloaded state. This action is clearly illustrated in Fig. 16 showing a photographic reproduction of a strip ruptured at a low arcless voltage. A portion of the strip was surrounded by an inactive environment, while another portion was surrounded by the active powder, an arrangement frequently used. It will be noticed that while a large portion of the strip was reduced to a molten condition, yet only that portion surrounded by the active material fluxed and ruptured. Aside from the material named, the other ingredients of the filling require careful selection.

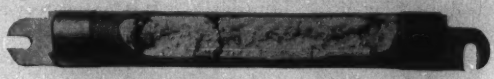


FIG. 17.—Short-Circuit Rupture of 500 V. 50 A. Fuse, Showing Combination.

By the use of such combining material around the fuse strip, other features of advantage are obtained. The combination between the metallic oxides with the environment absorbs the energy of any destructive arc or resulting explosive effect, which may tend to maintain itself under other conditions. The combination of the elements in the manner described is, however, equally as valuable in buffing the break, as a long continued and gradually lengthened arc. The merging together of the metal of the fuse strip and the material of environment necessarily causes a gradual increase in the resistance of the structure between the terminals, which is obviously, in order to make the device operative, a gradation from the practically negligible resistance of the intact wire to the absolute break resulting after a complete combination has been affected, and the metallic strip turned into a non-conducting mass. Fig. 17 shows the interior of a 500-volt, 50-ampere fuse short-circuited at that voltage with the resulting

combination. The advantage of this absorption of explosive energy, and the gradual, although rapid letting down of the current, is obvious.

By no means is the mere fact that an enclosed fuse stands the explosive action of interior rupture, sufficient to attest its satis-

FIG. 18.—Solid Packed Fuse Ruptured by Overload at Low Arcless Voltage. Note Central Location of Rupture.

factory operation under every other condition. After the explosive effect has been subdued or eliminated, the fuse is then subjected to the entire potential of the circuit ruptured. Unless the break is then free from any conducting quality under that particular potential a very slight leak may still be sufficient to result in a heating effect which soon causes afresh a most severe arcing, and the destruction of the entire device. It is for this reason that the condition following a short-circuit, if carried without destruction by the fuse, is sometimes not as serious a test as a gradual slow arcing break, although the instantaneous shock to the fuse is far more severe in the former case than in the latter. If, however, it is considered that a short-circuit will disrupt the maximum length of fuse metal while the slight overload may cause only a very short break, the reason for this condition will at once be seen. Fuses of the enclosed type should, therefore, be tested under both conditions. Those in which the construction and arrangement of the parts is such, that a carbonization or similar formation may result, due to the character of the materials adjacent to

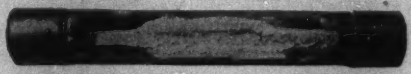


FIG. 19.—Solid Packed 500 V. 50 A. Fuse Ruptured by Overload at Normal Voltage.

the ruptured metal, would seem to be particularly subject to this condition, while those in which the entire wire is surrounded with materials free from these or similar defective properties, would be apt to operate in a far superior manner.

Whether or not the complete enclosed fuse will stand severe short-circuit shock also depends to quite an extent on the centering of the wire rupture approximately midway between the ends of the tube, so that its resulting effect may work against sufficient filling material and fusible metal on each side. Fuses in which the connection between the fusible wire and the exterior terminals is made at the end of the tube, are defective unless the ends of the wire or strip are proportioned to act as terminals only, and are therefore of better conductivity than the more centrally located section. Fig. 18 shows a solid packed fuse ruptured by overload at low voltage, and Fig. 19 at normal voltage.

The fact that if properly operative the exterior of the enclosed fuse gives no indication of the condition of the interior wire, is undoubtedly a substantial objection to this type of protective de-

FIG. 20.—2500 Volts, 50 Amperes.

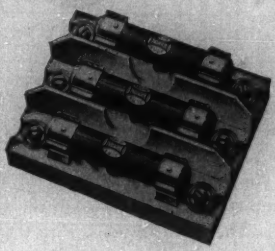


FIG. 21.—220 Volts, 25 Amperes.

vice. Any arrangement for the purposes of exterior indication must necessarily be simple, safe and cheap. The writer has devised several indicating arrangements, and the method adopted, probably meets these requirements. In shunt across the interior fuse is placed a very fine high resistance wire containing a minimum of metal, and placed wholly or partially on the tube exterior with its ends connected to the fuse terminals. The condition of this little indicator wire at all times shows the condition of the interior fuse, since a rupture of the interior fuse at once causes a rupture of the indicator. A peculiar feature, however, in the operation of this auxiliary device, is the fact that on all except the smallest capacity fuses it disrupts practically without any arc whatsoever. The reason for this condition is at once found in the fact that the main fuse is gradually losing its conductivity on rupture, and is at some

particular instant equal in resistance to the indicator. The equally divided current is then sufficient to rupture the indicator, which is still shunted by the increasing resistance of the interior fuse, in which the final break of the circuit really occurs. This

FIG. 22.—500 V. 400 A. Complete Cutout.

fact is amply proven by short-circuiting an indicator wire on a fuse tube with and without an interior fuse in shunt with it. The flash in the latter instance is comparatively severe, while in the first it is entirely negligible.

The appearance of some of the solid packed fuses in their completed form is shown in the accompanying Figs. 20, 21, 22, 23. These illustrations, with the various modifications shown in

FIG. 23.

the construction of the terminal fittings, accessory fuse blocks and fittings, are self-explanatory. The general dimensions of these fuses for the different commercial voltages are given in Table A.

## TABLE A.

### Length and Diameter of Fuse Tubes.—Solid Packed Fuses.

| AMPERES. | 1 to 8 | 10 to 15 | 20 to 30 | 35 to 50 | 60 to 100 | 110 to 150 | 160 to 200 | 300 to 400 | 500 to 600 | 700 to 800 | 900 to 1000 | 1 to 10 | 15 to 25 | 30 to 50 | 60 to 100 | 110 to 150 | 160 to 200 | 300 to 400 | 500 to 600 | 700 to 800 | 1 to 12 | 15 to 30 | 35 to 50 | 60 to 75 | 80 to 100 | 1 to 12 | 15 to 30 | 35 to 50 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Moximum length of fuse tube to outside of caps. | $2\frac{5}{16}$ | $2\frac{1}{16}$ | $3\frac{3}{16}$ | $3\frac{3}{4}$ | $4\frac{1}{8}$ | $4\frac{1}{8}$ | $4\frac{5}{8}$ | $4\frac{5}{8}$ | $6\frac{3}{8}$ | $6\frac{3}{8}$ | $7\frac{1}{8}$ | $4\frac{5}{8}$ | $5\frac{1}{2}$ | $5\frac{3}{4}$ | $6\frac{1}{2}$ | $6\frac{1}{2}$ | $6\frac{3}{8}$ | $6\frac{3}{8}$ | 10 | 10 | $5\frac{3}{4}$ | $5\frac{3}{4}$ | $6\frac{1}{4}$ | $6\frac{1}{16}$ | 7 | 24 | 24 | 24 |
| Diameter of Fuse Tube. | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{1}{2}$ | $\frac{3}{4}$ | $\frac{7}{8}$ | 1 | $1\frac{1}{4}$ | $1\frac{1}{4}$ | 2 | $2\frac{1}{2}$ | 3 | $\frac{3}{8}$ | $\frac{1}{2}$ | $\frac{3}{4}$ | 1 | $1\frac{1}{4}$ | $1\frac{1}{2}$ | 2 | $2\frac{1}{2}$ | 3 | $\frac{1}{2}$ | $\frac{3}{4}$ | $\frac{7}{8}$ | $1\frac{1}{8}$ | $1\frac{1}{2}$ | $\frac{3}{4}$ | 1 | $1\frac{1}{4}$ |
| | 220 VOLTS. | | | | | | | | | | | 500 VOLTS. | | | | | | | | | 2500 VOLTS. | | | | | 10000 VOLTS. | | |

HOT OVERLOAD TIME INTERVAL CURVE—25 AMP. FUSES.

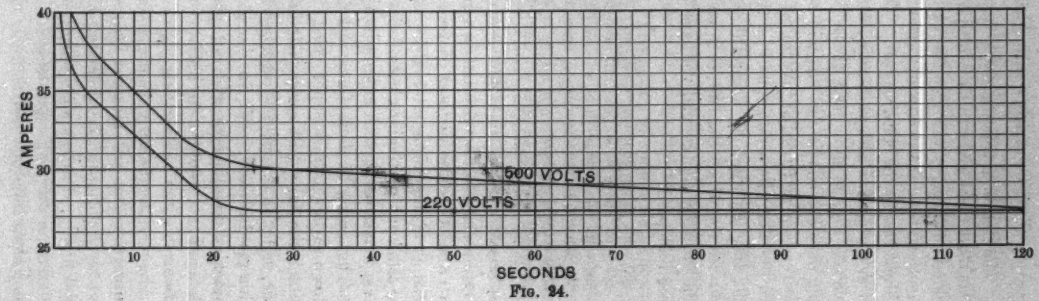



Fig. 24.

### The Operation and Use of Enclosed Fuses.

The desirable time-interval function in properly constructed enclosed fuses gives to this form of fuse protective device a decided advantage, owing to the variation and adjustment of the overload time interval which can be obtained by very simple alterations in the construction. This feature of the device makes it available for almost every class of electrical service. The curves, Fig. 24 show how the solid packed fuses act under varying overload conditions. It will be noted that the time interval increases in an irregular inverse ratio to the percentage of overload. In practice, the arrangement of this time interval function of the fuse is judged by a careful consideration of the particular service for which the fuse is to be used. In standard fuses of the ordinary commercial voltages the following adjustment has been adopted.

220-volts below 20 amperes will carry 25% overload for 10 to 20 seconds.
220-volts above 20 amperes will carry 25% overload for 25 to 40 seconds.
500-volts below 20 amperes will carry 25% overload for 15 to 30 seconds.
500-volts above 20 amperes will carry 25% overload for 30 to 60 seconds.
2500-volts below 10 amperes will carry 25% overload for 10 to 20 seconds.
2500-volts above 10 amperes will carry 25% overload for 30 to 45 seconds.

These overload time intervals may perhaps appear small for certain classes of service but in arranging and adopting a standard overload time for all fuses of a certain voltage, it was essential that an average time interval be taken, and not one only adopted to some one particular class of service. Special fuses are, however, constructed with any desired time interval.

The rating of these fuses is based on the lines already laid down earlier in this paper, that is: the rating is the current which the fuse will carry indefinitely without rupture. They are, as far as possible, adjusted so that any excess current above this rated capacity will, in time, rupture the fuse strip. But practical manufacture will not permit, nor does practical service demand this condition to hold to more than within five per. cent. above this maximum rating.

In the manufacture of these fuses, however, every effort is made to refine each element by a series of tests practically prohibiting variation in the character or quality of materials employed, and finally, after the device has been completed, it is given a maximum carrying capacity test for a sufficient time to guarantee its proper interior construction. The necessity for dimensional

and structural accuracy in the fuse strip which increases with the conductivity of the fuse metal employed, has received particular attention. Aside from the very careful micrometer gauging of the strip, each strip is measured for resistance by a rapid drop of potential method.

The writer has been frequently asked whether the carrying capacity of such a fuse under normal conditions is affected by the action of the environment, it being assumed that since the environment co-acted with the metal in forming a combination on rupture, and when the metal was in a molten condition, that this action in a milder form might be present under normal running conditions. It must first be remembered that the environment does not combine with the metal, but with the oxides of the metal, under the action of the heat, and that this combination is only effected when a certain definite temperature or condition of the metal has been reached. The action of such a well-known flux as borax or similar acting material is well understood, and it is known that any action between this material and metallic oxides occur only at a definite temperature permitting of the flowing together of the melted borax and oxides which it dissolves.

In order to determine with exactness whether such condition could exist, fuses have been subjected to their normal current for a long time, and then carefully examined. Other fuses have have been subjected to actual service running tests in which the maximum carrying capacity of the fuse was passed through it several hours each day for a period extending over a month or more. In both cases the fuses continued, and are continuing, to carry their rated capacity, and an examination of the strip has shown no attack.

The temperature at which the disrupting action begins is only reached after the overload current has been on the fuse for the allowed time interval, or within a very close practical approximation of it. The writer has even taken fuses and passed a certain percentage of overload current through them for a time, less than the limit for that particular current, and has afterwards carefully examined the strip without discovering any deterioration therein.

The matter of variation in time interval for any particular amount of overload in the solid packed type of fuse when hot and cold, has been open to quite some discussion.

Table B shows the hot and cold blowing time for a definite overload on several sizes of the writer's fuses as determined from recent tests.

It may appear that this type of fuse has a larger ratio between its hot and cold blowing point for a definite overload than a fuse constructed with an air chamber, as shown in Fig. 9.

TABLE B.

HOT AND COLD OVERLOAD TIME—SOLID PACKED FUSES.

| Rating. | Carried. | Time | Overload | Opened. | Ratio Hot to Cold |
|---|---|---|---|---|---|
| 500 v. 40 A. flat single fuse | 40 a | 1 hr. | 50 a<br>50 a | 55 sec.<br>210 sec. | 11 to 42 |
| 500 v. 25 A. flat single fuse | 25 a | 1 hr. | 30 a<br>30 a | 45 sec.<br>195 sec. | 3 to 13 |
| 2500 v. 50 A flat single fuse | 50 a | 1 hr. | 62½ a<br>62½ a | 30 sec.<br>120 sec. | 1 to 4 |
| 220 v. 10 A. round single fuse | 10 a | 1 hr. | 12 a<br>12 a | 10 sec.<br>30 sec. | 1 to 3 |

A few tests of an air space fuse under such conditions indicate that this assumption does not hold good. These are given in Table C., and a comparison with Table B. demonstrates, at least

TABLE C.

HOT AND COLD OVERLOAD TIME—AIR SPACE FUSES.

| Rating. | Carried. | Time. | Overload | Opened. | Ratio Hot to cold. |
|---|---|---|---|---|---|
| 2000 v. 50 A mul. fuse. | 50 a | 1 hr. | 62½ a<br>62½ a | 60 sec.<br>690 sec. | 2 to 23 |
| 2000 v. 15 A single fuse. | 15 a | 1 hr. | 18 a<br>18 a | 20 sec.<br>90 sec. | 2 to 9 |

from the sizes tested, that the air chamber fuse of the construction tested, is equally or more subject to this variation than the other type. The reasons for the existence of this condition, whether it be in the one type or the other, have already been discussed. It is to be noted that the air space fuses tested employ a relatively larger bulk of metal and environment.

In order to further test the relative advantages of these two types of fuses, comparative short-circuit tests were made, and the following record of these tests shows the advantage for rapidity of action to again be with this form of solid packed fuse.

COMPARATIVE SHORT-CIRCUIT TEST AIR SPACE AND SOLID PACKED FUSE.

50 A. 500 V. rated capacity of each fuse. Connected in series and thrown across 500 V. Conduit contact rails. Solid packed fuse opened alone. Air space fuse held.

50 A. 2500 V. rated capacity of each fuse Connected in series and thrown across 500 V. feeder at laboratory. Same result as in prior test.

Correctness of "Solid Packed" rating tested before short-circuiting.

Reasons similar to those already stated are potent in effecting this result also. In determining the rating of any enclosed fuse, it is very essential to give it ample time.

Experiments made to determine the carrying capacity of fuse strips such as used in these solid packed fuses when covered with the environment, and when entirely air surrounded and exposed has demonstrated with the several sizes of strips tested, that the current-carrying capacity of the strip is the same, whether it is encased or not. The time interval necessary to bring it up to a definite temperature varies in the two conditions as shown by the test record in Table D. of a 40-ampere 500-volt fuse strip, which may be taken as a fair sample. The smaller fuse strips show a slightly increased capacity when encased.

TABLE D.

RATING TESTS OF 500 VOLT, 40 AMPS. FUSE STRIPS.

| | Tube. | Fuse. | Term'l. | Filling. | Run at | Time. | Checked or References. |
|---|---|---|---|---|---|---|---|
| Enclosed | ¼ x 5¾" | .018 x .13 x 3" | .11 dia. | All active | 40 a | 1 hr. | |
| | " | " | " | " | 50 a | 55 sec. | Opened. |
| | " | " | " | " | 50 a | 3½ m. | Opened. |
| Exposed | None | " | " | Air | 40 a | 15 m. | |
| | " | " | " | " | 50 a | 12 sec | Opened. |
| | " | " | " | " | 50 a | 25 sec. | Opened. |

Fuse and terminal wires 5¾ between contacts.

Distance between centers of posts 6¼".

Owing to the fact that the above tests indicated that the uncovered fuse required a far shorter lime for its operation than the covered fuse, it is decided to make a comparative short-circuit test of these two arrangements. A record of this test is given below:

COMPARATIVE 500-VOLT SHORT-CIRCUIT TEST OF FLAT STRIPS IN SOLID PACKED CASE AND AIR EXPOSED.

Open and enclosed fuses similar to those used in Table C, rated 40 A. 500 V. enclosed. Flat strip .018 × .13 × 3″ between copper terminal wires .11 diam. 6½″ between center of contact posts.

*Exposed Fuse Strip Alone.* Very severe arcing and burning of terminal wire back to posts. Break 6″.

*Exposed Fuse Strip in Series with Enclosed Strip.* Both fuses opened but exposed strip simply disrupted to terminal wires without any burning and only slight snap. Break 3″ in each exposed fuse.

It will be noted that instead of being slower than the uncovered fuse, the encased device was equally as rapid, if not more so. This seems to lead to the deduction that on short-circuits the disruption of the strip depends on the instantaneous energy impressed upon it and its specific heat and mass, and the radiation and conduction from the strip to its environment is negligible.

The writer has constructed and operated fuses of the type described, ranging in capacities up to 5000 to 10,000 volts and 30 amperes and 500 volts with 600 amperes continuous running capacity, but is prepared with data already in hand to furnish similar devices up to 1000 amperes on 220 or 500 volts and 50 amperes on 10,000 volts. These fuses are all constructed so as to singly open circuits up to 2500 volts.

It has frequently been suggested that for protection on high potentials a number of lower potential fuses in series might be available. Such an arrangement is, however, defective, owing to the fact that under conditions of short-circuit rush the shock may be so instantaneous that the disruption of one of these fuses may precede the other. Such condition will frequently act disastrously upon the particular fuse called upon to stand the first blow, which, until shared by another fuse, involves the opening of the total energy of the short-circuit.

On a similar basis the use of several fuses in multiple has been suggested where one fuse having the total aggregate capacity was not available. Such shunting of comparatively low resistance paths necessarily requires the greatest accuracy in adjusting the resistance of each so that division of the current may be equally shared. The impracticability of doing this is obvious, and it is for this reason and others that this arrangement is discouraged, and every attempt made to produce a single self-contained tube, having the carrying capacity desired, and capable of working

satisfactorily under all required conditions. The shunting of ordinary circuit-breaking devices by a proper enclosed fuse is an excellent arrangement and permits of most extensive application. All arcing can in this way be eliminated and breaking appliances may then be used at much higher potentials than these for which they are adapted alone.

Aside from the particular constructions noted, which are particularly applicable to fuses for electric lighting, power and similar services, the writer has developed another new type of enclosed fuse for delicate work. In this direction it has been possible to obtain accurate and safe fuses having a rating of .005 of an ampere, and which blow in 15 seconds at .01.

## Enclosed Fuses *vs.* Other Protective Devices.

A discussion of the relative merits of fuses and electro-magnetic circuit breakers is entirely unnecessary in this paper, since the relative merits of these devices is well understood and appreciated. With a fuse device of the character mentioned available, however, the advantages of the circuit breaker are limited to the applications where a very rapid resetting of the protective device is essential, and where the protective device is desired absolutely without any time factor on overloads. Where such conditions exist it is more frequently a question of adopting a device whose function is to serve as a "circuit-breaker," and which need not necessarily fulfifl the ideal requirements of a circuit-protector.

It is unquestionably a fact that the perfected forms of both devices have enormous fields, but it cannot be denied that if the device to be protected has a time over load factor, that the ideal method of protecting it is to use in conjunction therewith a time interval protective device. No device has as yet been produced which can perform these functions in a simpler and more efficient fashion than a properly designed enclosed fuse. Aside from this feature, there is unquestionably an enormous field in which the perfected fuse protector is alone.

## Conclusion.

In describing and discussing the various features of the new device of which this paper particularly treats, the writer does not intend to imply that perfection has been reached, nor that the device in its present condition is capable of meeting every possible condition of unusual service. It is, however, believed that the

principles herein discussed are based on good foundations, and that similar devices constructed on these lines can be built, capable of accomplishing results heretofore impossible with the types of fuse and other protective devices in common use. With the introduction of higher potentials in every direction, and the desire to improve the safety factor of electrical service to the utmost, it is believed that the enclosed fuse protector is essentially a necessity, and its entrance into the electrical practice of the present, is undoubtedly but the beginning of a perhaps universal application.

## Discussion in New York.

[See p. 605 November issue.]

The President:—Gentlemen, we have listened to a very interesting paper upon a very fascinating and interesting subject, no less a subject than the only gap which exists in the electrical fence around the world, and the question as to how that gap shall be filled and who shall fill it, is one of very great importance to everybody concerned, to ourselves as electrical engineers and to the nations who dwell upon the sides of this great gap, as citizens of the world. I hope that the discussion upon this subject will be as interesting as the paper to which we have listened.

Mr. Herbert Laws Webb:—Mr. President, I have listened to Capt. Squier's paper with a very special interest, because cable-laying is my first love, and however circumstances may drift you apart, I think it is always pleasant and grateful and interesting to hear of one's first love.

I may say that I think there is very little to debate in Capt. Squier's paper except where he raises debatable points. Those occur in connection with the traffic, with the proposed working in a continuous manner. As regards the feasibility of the scheme itself, I think there is no question at all in the minds of submarine cable engineers, especially as regards the American route; and even as to the more ambitious British route, firm offers have been made to lay the whole series of cables, including the long Vancouver-Fanning section, so that it is quite evident that the most experienced engineers do not fear any difficulty, either on account of the great length of the section or on account of the great depth of water encountered. The average depth of water is rather greater than the average depth encountered in other oceans. But the improvement in the manufacture of submarine cables, the improvements more particularly in the manufacture and protection of the sheathing, and the improvement in the art of cable repairing have caused the fears that existed about ten years ago with regard to a depth of 3000 fathoms to have disappeared from the minds of practical cable men. So that as regards the feasibility of either scheme, I think we all agree with Capt. Squier that there is at present no doubt whatever. I think that the American scheme is very much the preferable one on account of it having a much shorter distance for its longest span than the British scheme. There is no doubt that the great length of 3500 miles that would be required in the section between Vancouver and Fanning would seriously limit the speed of the whole series of cables. That difficulty does not exist with the American scheme, where the longest section is something under 2500 miles—no longer than several of the present North Atlantic cables. Then I think the American scheme has the further advantage of going to the Hawaiian Islands, which is already an active center of trade and is no doubt destined to become of a great deal more importance than it is at present.

Where I rather take issue with Capt. Squier is in the proposal that the cable should be worked as a government institution. I think that practically the only argument in favor of that proposal is that the government can raise money at a lower rate of interest than a commercial company. The very amount of capital required for the Pacific cable has no doubt deterred private capital from establishing it up to the present time. There are numerous capitalists in this country who have been anxious to lay the cable; gentlemen who have had good experience in managing cable properties; but they are not quite willing to incur the entire risk, and have refrained from active measures pending some assistance from the government. But I think that as a general rule, and my experience, which extends over a few years, and into quite a number of different countries—is that the telegraphs and telephones do not flourish under government management. I am not quite sure that even the post-office, which has become by a sort of divine right a government monopoly in all countries, would not furnish us a better service if it were run by a commercial company or by commercial companies in competition. I rather think, even in this country, if commercial companies were operating the post office service, we would get better results than five days for a letter and its reply between New York and Chicago, or three days between New York and Boston, and I think that a letter written for New York and posted in New York would sometimes be delivered in New York on the same day. If you go into other countries, in Europe—I should incline to make an exception of Great Britain, because I think the British telegraph service is about as good as you can find anywhere—but in the continental countries I think that the government management of both telephones and telegraphs does not give as good results as company management, which still exists as regards telephones in one or two countries of Europe, and, strangely enough, which exists in one country as regards the post-office. It was rather a surprise to me to find only a few months ago in a country where the government is most rigid in its monopoly of means of communication, that there was a company operating a post-office in some of the biggest cities. In Berlin, and I believe in Hamburg, there is a company running a post-office service for the local delivery of letters in competition with the Imperial post-office, charging lower rates and furnishing a more rapid service, and the Imperial post-office feels the competition of this company so much that it has taken measures to buy it out, and is offering to lower the rates of postage for local letters in the large cities, if it obtains a complete monopoly of the post-office business.

Now when it comes to the proposal of operating a cable continuously, of providing such rates as to attract a sufficient amount of traffic to fill up the cable the entire time—Capt.

Squier reckoned on a traffic of some five million words a year each way—I think he overlooks two or three characteristic points of cable traffic. He evidently counts, by his comparison with the mails, on attracting a large amount of purely personal, private messages. Now I think it may be taken almost as an axiom that the urgency of private communications varies inversely as the distance that you are apart. Private messages as a rule, private telegrams, refer either to making appointments or to breaking appointments or to making excuses for not keeping appointments. They are generally addressed by people who are close together, who are in the same country, within a few miles of each other, or in the same city. I think the large majority of private telegraph messages are caused by the people who send them having to meet shortly, or having met shortly before, or not having been able to meet; the message of congratulation and similar communications probably make up a very small proportion of the total number of private telegrams. Now it seems to me that when you get away, when you are separated by the sea, there is very little occasion to send urgent private messages. As a rule, the urgent private messages that go by cable are on matters of life and death; you you would send those anyhow, no matter what the cost was, and I don't think a lowering of the rate will induce any very large increase of private messages. You cannot imagine the ordinary letters that people write to each other when they are separated by the sea being condensed in any possible manner so as to go in a cablegram. I happen to have relatives all over the world and it seldom occurs to me to write at all to the most distant ones, and certainly it never would occur to me to send them a telegram at any price. That is my experience and I think it is largely that of others.

Then I think it is overlooked in this proposition that the great difference in time between places separated longitudinally by the oceans causes even business messages not to be of great urgency as regards *hours*. If I am in an office say in New York and get a telegram from London requiring a reply, if that comes in in the middle of the day it makes no practical difference whether I send the reply during the remainder of the working day or at night, because it is already four or five o'clock in the afternoon in London, and it makes no practical difference whether they receive a business telegram at that hour in the afternoon or the next morning. So that if there was a night rate, a lower rate during the night, I think the majority of business telegrams would be kept for that night rate, and that would of course apply very much more in the case of a Pacific cable, where the difference of time is much greater. Between New York and Manila the difference of time is eleven hours, so that what is our night is practically their day and if there were a night rate it would simply mean that all the business messages which have to go anyhow would go at night, instead of going in the day. I

think that is the reason why no night rate has ever been instituted by the Atlantic cables. You could not have a finer opportunity for experimenting with rates and adopting differential rates than in the Atlantic cables. There are practically no two countries in the world where private and social relations are so intimate as between England and America and there are probably no two countries where the business relations are so close, and it seems to me if it were possible to differentiate the rates other than by the ordinary difference between press and business messages and government messages, if it were possible to introduce a night rate for purely private messages which would yield a profitable result I think it would have been done already.

MR. T. E. HUGHES:—There is one question I would like to ask Capt. Squier in connection with his suggestion of having a connection between the proposed British cable and the proposed American cable, what influence would it have on the operation of the American cable if the English cable be under government control and the American cable under the control of a corporation? It occurs to me that there is a point there that is decidedly in favor of American government control. For instance, if there should be any difficulty between the nations in the far east, they might arbitrarily exclude American messages; but if by treaty our business could be switched around on the English cable a condition would arise to protect our interests, while under a commercial control such condition could not exist.

Again, the gentleman who has just addressed us takes up the discussion of a differential-rate. While possibly his remarks apply in so far as a night rate and a day rate may exist, yet taking our business with our extreme Pacific possessions—the Philippines—where we are under a two-weeks' delay or in other words two weeks to reach them other than by cable, it occurs to me that a sliding scale would decidedly operate in favor of the operation of the cable. In other words a cablegram to be delivered to Manila subject to delay of one, two, three, four, or even five days could be transmitted at a mere nominal cost as compared with the instantaneous delivery and still make a ten day issue in favor of the use of the cable.

Another point arises as to whether there is any data extant as to what revenue could be anticipated on operating an American cable as to its commercial revenue as compared with what we know (and the author has so exhaustively given us) the United States government is to-day paying. In other words what percentage of the entire amount of business being done with our Philippine possessions, does that represent? If the government's contribution is fifty per cent., of course we can see that the net revenue to a commercial corporation, or the

government itself, would be double. I am interested as to whether such data is available.

CAPT. SQUIER:—In answer to Mr. Hughes' remarks I will say in regard to the other data that it has been a great deal of trouble to get this data together and we have written to the press all over the country a circular letter asking them to give us an account of their Philippine business. We know what rate they pay. I have not given it, purposely in this article, because I do not care to at this time. We asked them provided they are at perfect liberty to do so, to furnish us with information of what their cable bills are monthly for the last six or seven months. As I say, it is difficult to get this together and unfortunately now I have not it at hand. It is coming in gradually and we hope to have something before very long —not what will be done but what is being done now. We know what the government is paying. It is paying approximately a thousand dollars a day in cash to foreign corporations for messages. There is no question about that, for we have counted the words. We also know that the short span of cable about six hundred miles long from Hong Kong to Manila, the cost of which could not have been more than half a million dollars, is now earning seventy-five cents a word for every word that goes over it, and that is three times the rate to Europe, and is the interest on three and a half million dollars, enough to lay a whole Atlantic cable. This company had from Spain a cable right to land in the Philippine Islands, and that is the price they are exacting now. The other data, I am sorry to say, is not in hand, and the general data that I gave $150 a mile is taken from the average earning power of all the long cables of the world. I believe that to be a very low estimate. I have merely given it for what it is worth. I have no doubt, from what I can learn, that this enterprise will be a paying enterprise from the very beginning, and particularly if it is a government enterprise, because the government can do it cheaper than any one else. It can borrow money cheaper, and is not required to earn any dividends at all, simply earn the interest on the money and keep the plant maintained as a permanent asset, making prudent provision for a sinking fund, which I have endeavored to make here in this table given on page 611.

In regard to the other points that were brought up—in regard to differential rates, I have been unable to come to any other reasonable conclusion than the one that a cable, particularly a Pacific cable, should be operated all the time. I cannot see any reason for not operating continuously, for the reasons which I have given in this paper, that the operators sit there, and it practically costs nothing more to maintain it than if you did not operate it. You have to keep the cable ships, etc. The cable does not deteriorate by sending messages, and it does not harm it in the least. If the cable is idle for an hour, it is an absolute loss

to the world. I would say, send to the press for nothing rather than allow it to be idle. It is a case of a ten million dollar plant idle for four or five hours in the day, when it doesn't cost any more to use it than it does not to use it. But if it is a government enterprise, with all of our soldiers in the Philippines, and people blockading Washington to get information, if there are any idle periods, I am sure they could be used to advantage to communicate with the Philippines. It is really pathetic to witness the large amount that is charged to send a few words to the Philippine Islands, which is now being filled up with our relatives and friends, whom we wish to communicate with. I remember one particular instance, in the last day or two, where, at the end of four days, a father had spent something like $100 to find out whether a bullet had gone through his son's body or not. This is an actual case, and such cases are occurring now all the time, and the rates are prohibitive and absolutely limit the kind of traffic. The difference of time between the countries that has been mentioned—of course, that is understood very well. It is well known on any long cable, but you have such a lee-way in the time. Your only competitor is a mail ship, which requires two or three weeks, and the objection that patrons would all take the night rate, or the cheap rate, seems to me erroneous.

Of course when you attempt to establish a series of differential rates, as indicated, you would probably first get it wrong. You might guess at it, and say for class No. 2 the rate will be half what the maximum rate is. You might allow on the back of the blank, three or four hours for delivery. In other words, readjust the rates frequently until you find out what is the exact schedule of rates that would fill the cable continuously. Such a series of rates would be easily found. We might even classify traffic into ten or twelve different classes, if necessary. We have now four classes in the mail matter on the steam train between here and San Francisco. If we have a single thread between here and another hemisphere, I cannot see why we should ever let it be idle at all. I cannot see any reason why it should not be used continuously, because you can classify the business in as many classes as experience indicates is necessary. You might have a right-of-way rate, which would be the very highest rate, when a man wants his message to go at once, and the next rate might be very close to that rate. If you find that they are all taking this second rate, you would simply move it up so near the first that they would not find it sufficiently advantageous; so that I should think that four, or five, or six different rates could be adopted, and the last would involve say a week's delay. Classify all traffic, and when slack time comes send them in their order. It simply uses those idle hours that are no use to any one at present, and costs nothing except the price of the operating clerks, which, as I have shown, is an inconsiderable amount of the total annual

expense of the plant. You simply require an insignificant expense to use a ten or twelve million dollar plant. From a business standpoint, it is a most unique set of circumstances. In a manufacturing plant you cannot run at all times, because the plant wears out, and the coal bill is too large, and you have to engage too many more employees. Referring to the Atlantic cables—they are not now operated continuously, but I believe they soon will be. I think the reason that this policy has not already been adopted in the Atlantic is because of the peculiar character of the cable business, and the peculiar history of ocean cabling. Fifty years ago it took a good deal of confidence to invest any money in cable business. It was a very hazardous matter, and rates had to be very high. It is not easy for an Atlantic cable company now to do anything suddenly, even if it wants to. They are bound up with their competitors in mutual moral obligations, besides legal ones. But in the new field of the Pacific, if the cable is run by the government, it can advance and treat every one fairly. Treat the land systems perfectly equitably. That is, turn over unrouted messages to them in an equitable proportion. Have no favor shown any institution, individual, or corporation, or any other person, and a government enterprise, is the only solution I can see to prevent the extension of present monopolies, because any cable system must have traffic arrangements with a land system. A cable is useless without a land system at each end, covering the territory that the cable is to serve. Therefore take the example of the Pacific. Suppose it is laid by a private corporation. That corporation is immediately obliged to form some relation with particular land systems. The other land lines are, of course, excluded and out of this arrangement; so that what happens is that land companies combine with the cable, just as it is now – enlarging the present state of affairs into a larger organization, which keeps rates so high. So that I see no wise solution, except to put the cable down in a fair open field by the government, treating everybody alike and running the cable simply to maintain American commerce itself, not to earn dividends. I believe a Pacific cable will lower the through rates, and it will probably lower the Atlantic cable rates also, because, as I could have shown you, the present rate now between Europe and the east, via the Great Northern and Japan, is about $1.50, as I remember, and over the southern route, by the Eastern and China, is something like $1.90. It is in evidence before the British Commission that the Canadian Pacific Railway has agreed to lay down messages in Vancouver from London over the Atlantic cables for 25 cents. Therefore it can be assumed that we can put English messages in San Francisco for 25 cents on the through-rate plan, so that if we can put the cable part of the message at 75 cents, we would make a $1 rate or $1.25 rate, at most, between London and Japan, which will either cause the eastern rate to be lowered or else divert the European

traffic over the Atlantic cable system. That is why I made the statement that if this cable is put down and run by the government, I think it will operate to readjust the through tariff rates from the east, because the new route has long spans, few transmissions, and few chances for error, and you cannot compete with it.

About ten or twelve years ago all mails used to go east. Finally they were diverted west, and the through mails cross the American continent in a large proportion. There are two ways around the world, and it is a great advantage to have a competitive route both ways. Up to the present there has been only one way, telegraphically. By putting this last link in, it is going to make a greater difference than any other single telegraph line ever did, because it is going to join each point by two routes.

In regard to the differential rates, I am glad to hear the opinions that have been expressed. I have asked a good many of the Atlantic cable experts why they do not work the cables continuously. It seems a sin to leave a several-million-dollar plant idle, when it costs nothing extra to use it. They might give it to the newspapers, so that we could learn something about these countries over there.

I really cannot come to any other conclusion. The difference of time does not enter at all, because you classify everything, and when the cable becomes idle, put in class No. 2, or No. 3, or whatever it is, according to its class.

I would be glad to hear other views in the matter—it is a conclusion that I cannot see a flaw in.

THE PRESIDENT:—The subject, of course, has two distinct sides: The engineering side and the commercial side. I think as engineers we all agree that the cable can be laid; it is only a question of how much it costs. We all agree that if one cable cannot be kept working that with duplicate cables the system can be kept working. In any case we should have in a certain sense a duplicate cable on the other side of the world. So that from an engineering standpoint there is no difference of opinion at all between us except in regard to minute details, as to the question of cost, as to question of size of the cables, and as to the best positions in which those cables could be laid. When we come, however to the question of the commercial aspect, we get differences of opinion. This aspect of the question has, however, been more thoroughly and more practically studied than even the engineering aspect of the question, because it has come home to every manager and every administrator of submarine cables and of long telegraph lines ever since cables and land lines have been initiated.

There can be no doubt, I suppose, as a broad proposition, that a government can raise money on better terms than any individual or association of individuals, because its credit is better; and moreover a government can also afford to make experiments

upon rates better than any individual or collection of individuals owning a telegraph or telephone scheme. At the present time when a corporation, as is usually the case, owns the cable, it has no object, primarily, in making high rates. It has an object in getting a dividend, and its only object in placing the rates high is to enable dividends to be secured. But it would be just as well content in cutting those rates in half or reducing them to any desired amount if thereby it could ensure the necessary dividends to its stockholders. And it is a matter of experience that as you lower rates you do not get a corresponding return from the traffic to make up for the diminution. Eventually, after the public had been educated up to it I suppose that you would and must, perhaps, according to logic; but it takes time before the public can be educated to the greater facility, and to the use which an increased facility places at their command; so that if they have only to spend half as much money per word, to teach them to spend twice as many words. No doubt it would come in time. But during that time the dividends of the stockholders are falling-off and the cry is to the managers "This thing must not be. You must put the rates up again," and the rates go up.

Now when the government owns a system it is possible, of course, for them to say, "Wait a while; we will educate the people up. We can afford to wait until we have educated them up." And in that way there is, perhaps, a signal advantage in government control of cables and long telegraph systems. But otherwise I quite agree with Mr. Webb that upon the broad principles of finance and competition, private ownership is preferable. I think that the plan of filling the cable with traffic as Capt. Squier suggests, while it is eminently proper—is rather more Utopian than practical. In the first place there are many cables at the present time, long cables, that are busy day and night. I do not allude particularly to the Atlantic cables, because the condition of traffic, the ebb and flow of business between the two sides of the Atlantic is such as determines the rushes and periods of relaxation. But take the cable system of the world as a whole, and I know some cables where the operators do not stop except for relief. There may be exceptions occasionally, and, of course, Sundays are usually slack days; but I think it unsafe to say that long cables at the present time remain idle.

Then, if you are going to experiment down to the point at which you are going to fill your cable up on working days, on Mondays, Tuesdays and Wednesdays, on Saturdays when a foot ball game occurs you will be so crowded that you will not get clear for a month, and it is necessary to keep your traffic in hand so as to keep leeway as a reserve for rushes.

From a standpoint of general policy, no doubt Capt. Squier's position is right. The proper way to operate a cable is, theo-

retically, to keep it fully occupied with traffic. Theoretically he is right, that we should have low rates and learn to send all our messages at any time, private or public, that way. It is a matter of habit, and it is a matter of cost. If it were cheap enough we would all send our letters that way, no doubt. It would take a little time to learn how to do it. The difficulty has been that at existing rates if you lower them you cannot make a dividend. If the government is going to give a helping and educational hand we would all be benefited to that extent.

DR. M. I. PUPIN:—Mr. President, I am rather surprised, that in view of the fact of our having discussed here last month the possibilities of wireless telegraphy, that nobody should have mentioned this evening the possibility of settling this whole cable question by wireless telegraphy. You know that there is a great deal of discussion in the newspapers about the Western Union getting a permanent cable mopopoly to Cuba. It seems to me that the Western Union having a cable monopoly to Cuba, suppose you arrange to telegraph from Key West to Havana which is only about 90 miles; by wireless telegraphy, you would get around it. I think you could telegraph just as fast by that means as you can telegraph by a cable. It is simply a question of a little bit of work, a little bit of experimental refinement. I have but little doubt after thinking over this matter, that before long we shall be able to telegraph by wireless telegraphy over 1500 miles. Now if you can do that—I say if you can—just think of the possible changes in communicating between continents. This wireless telegraph is only in its infancy and it seems to be a very vigorous infant—growing very rapidly.

There is a distance of about 2400 miles between San Francisco and Honolulu. There you would have a relay station; another relay station between Honolulu and the other island, and for the rest you can do it without relay stations. Now Capt. Squier proposes two cable ships; one at the Philippine Islands and one at San Francisco or at Honolulu. Why not use these cable ships as relay ships. It seems to me that 1500 miles for wireless telegraphy is nothing so very serious. I think it was in view of the fact that wireless telegraphy is going to be a very important factor, and growing so rapidly, that it is quite proper for me to mention the bringing of wireless telegraphy into this very problem.

MR. J. H. HALLBERG:—I read with much interest a short article in the *Western Electrician* of December 23d, 1899, which seems to further assure us of the possibility of long distance wireless telegraphy. It is claimed in the article, that Prof. Reginald A. Fessenden and his assistant, Prof. Kintner, in the electrical laboratory of the Western University of Pennsylvania, have produced a receiver for space telegraphy, which is two thousand times more sensitive than the coherer of the Marconi system.

DR. PUPIN:—Two thousand times?

MR. HALLBERG :—Yes, two thousand times. And, it was further stated that it may be possible to send messages, through the medium of this improved instrument, across the Atlantic, with poles less than 200 feet high.

CAPT. SQUIER :—I might say that that is just what the government is now considering for service between Key West and Cuba, also between Cuba and Hayti, across the Windward passage, and then across the Mona passage to Puerto Rico.

MR. HUGHES :—If the President will excuse me, there is one more point. Has the author made any computation as to what amount of time is consumed in sending the one thousand dollars a day messages on our Pacific business, in minutes or hours? We are spending a thousand dollars a day on our Pacific telegrams; how many hours or minutes does that consume?

CAPT. SQUIER :—I don't know how long they take to send them.

MR. HUGHES :—I would say off hand, from rough figuring that probably it does not represent more than an hour a day. Allowing margin then of an increasing business of twenty to one, we then have four hours left for the influx of an abnormal increase in business. Consequently it seems to me that is a very vital point on the part of the author that we have a ten million dollar plant there that we operate only one twenty-fourth of its working capacity. If we reduce our rates to a commercial basis which will admit of an increase of twenty to one, we still then have one-fifth of the working capacity of the cables left for an influx of increased business on the part of the government or otherwise, which proves, I think, very conclusively that a differential rate of tolls of traffic is one of the strongest points in favor of the government operating that business. The government can demonstrate just exactly what would be the correct ratio as to the sliding scale, and it would represent an enormous revenue to a commercial corporation to protect themselves to prove the case before it is practically demonstrated. It very forcibly shows that the government is the only one that can take the Pacific cable and work out the problem that is yet unsolved.

[Adjourned.]

[COMMUNICATED, AFTER ADJOURNMENT, BY MR. HERBERT LAWS WEBB.]

As the discussion on Capt, Squier's paper reached into rather late hours, I submit a few further remarks in writing. I am by no means an opponent of low rates, but I do not believe that under normal conditions any possible rate would tempt the traffic that Capt. Squier reckons with. To consider the traffic that occurs during the existence of war as bearing on the results obtainable year in and year out in the commercial working of a long cable is like gauging the yearly traffic of the Broadway cars and the elevated railway from the traffic of New Year's Eve, when tens of thousands of people set out to drown the chimes of

Trinity Church, that on other nights of the year never even think of a church. In war time neither government departments, enterprising newspapers, nor private individuals having relatives at the front, count the cost of cabling. But in the piping times of peace, government, private and press messages, collectively, count for a very small proportion of the total traffic of long cables. That traffic is made up almost entirely of business messages, and under any arrangement of rates the character of that traffic will not change to any appreciable extent, for the simple reason that no steady demand for cable communication comes from any other than purely business sources. Business messages will go over cables no matter what the rates, and when rates are lowered more business messages will go, but only a certain amount more, because the supply even of business messages is limited. As was pointed out by the President, it has been found in certain cases that rates could be lowered too far—that the traffic did not respond to the cheaper rates.

Capt. Squier seems to have misinterpreted my reference to the effect on the traffic of the difference in time between places joined by long cables. The difference in time has the effect of making the majority of business messages non-urgent, as regards *hours*. For one hour in the day the stock exchanges in New York and in London are open together, and that results in a flow of messages for a few hours in the day that are urgent as to *minutes*, and produces what is probably the quickest telegraph service between any two points on the globe. But with the majority of business messages there is no such extreme urgency. Many business telegrams, in the ordinary course of affairs, are sent from New York in the afternoon, that is, after business hours in London, and are delivered in London either late at night or the next day. If there were a night rate, or any sort of deferred rate, these messages would be held until night, to secure the lower rate, and would be just as efficacious as they now are at the full rate. Between America and the Philippines the case is still stronger. There is no stock-exchange traffic, and by reason of the greater distance, the infrequency of mail departures and the complete separation of business hours, not one message in a thousand would be urgent as to hours, and practically the whole traffic would avail itself of a night rate, or of any sort of deferred rate that might be instituted. The mails between New York and the Philippines vary from four to six weeks in transit, so that even the preposterous suggestion of cablegrams marked to be delivered in three days would suit the purposes of a large proportion of business messages. No cable manager would want to have anything to do with classes of messages to be delivered in one, two or three days from the date of origin. Such messages would cause more trouble and confusion than twice the number dealt with in the ordinary way. But there is no doubt that even a three-day-on-the-way cablegram between points six weeks apart

by mail would serve the purpose of much of the present traffic, and a cheaper rate for such a service would simply have the effect of diverting a certain amount of traffic that would ordinarily pay the full rate into the three-day-delay class.

There are many things for which a certain and steady demand exists, but for which a very large demand could not be forced, even if prices were reduced to practically nothing. A wide-spread demand cannot be created for that for which the majority of people have no use, even if you offer to give it away. In the words of a famous American, it is a condition and not a theory that will confront the management of the Pacific cable, and in spite of the keen interest at present taken in Philippine affairs, that condition will not differ in the long run from those that govern the operation of other long cables.

## THE PARIS MEETING.

THURSDAY, AUGUST 16th, 1900.

The proposed programme for the Paris meeting in August next will embrace various attractive social features. Mr. T. C. Martin, of the Committee, cables from London that the Institution of Electrical Engineers will offer a dinner in London to the visiting members of the INSTITUTE on August 13th. The members of both bodies will take a special train to Paris on August 15th. The joint meeting will be held at the United States building at the Paris Exhibition on August 16th and on the evening of the same day a reception will be held at the British building, the headquarters of the British Royal Commission.

## SAMUEL DANA GREENE.

**Died January 8th, 1900.**

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Samuel Dana Greene and his wife were drowned while skating on the Mohawk, late in the afternoon of Monday, January 8th, 1900. They had started to skate at dusk; there was a strong wind blowing, which suggested the use of a skate sail, and when last seen alive they were skating rapidly down the river with the sail. Their bodies were found in the open water near Freeman's Bridge. There is little doubt that owing to the very rapid rate at which they were going, they were unable to stop themselves when they saw the open strip of water in front. Cries for help were heard, and assistance soon arrived, but the rescuers having no appliance at hand for getting at the bodies, which were some distance from the solid ice, valuable time was lost in returning to the shore for these. The body of Mrs. Greene was first recovered; she was still breathing, but all efforts to revive her failed. The search for the body of Mr. Greene was continued down the river for an hour or more, without success. The searchers finally returned to the spot where his wife's body had been found, and there found the other. The position of his body and the markings on his gloves indicated that Mr. Greene had stood upright on the bottom of the river, holding his wife's feet in his hands, and keeping her above water as long as possible. This incident was characteristic of the man.

The funeral took place at Schenectady on the 11th of January. There was a short service and prayer at the house, after which the bodies were taken to St. George's Episcopal Church, escorted by Company E, Second Regiment, and a detachment of the First Naval Battalion, under Lieut. Andrews. The services at the Church were conducted by the Rt. Rev. William Croswell Doane, Bishop of Albany. The pall-bearers were Mr. Greene's intimate friends of the General Electric Company and the Naval Militia. The Governor of New York and a number of his staff were

present. All business in the city was suspended for the day. After the services, the bodies were taken to Bristol, R. I., where the interment occurred the next day.

S. Dana Greene was the son of the late Commander S. Dana Greene, who was the executive of the "*Monitor*" in her fight with the "*Virginia*," at Hampton Roads, and who succeeded to the command after Lieutenant Worden was disabled, shortly after the commencement of the engagement. He came of a family which had been distinguished in the history of Connecticut from the time of the earliest settlement, and of which various members had been in public service at all times down to the present, as officers of the army, navy, and in executive positions.

He was born on October 24th, 1864, and consequently was 35 years old at the time of his death. Entering the U. S. Naval Academy in 1879, during the entire four years there he stood at the head of his class, and graduated number one in a class which had started with more than 100 members, but of whom only 40 succeeded in graduating. His career at the Academy was a notably successful one; even then he attracted the attention of his superiors, many of whom then predicted that his record would be one worthy of his distinguished ancestry. After graduation, July 1st, 1883, and two years' sea duty, he was commissioned an ensign. Obtaining leave of absence, he entered the Sprague Electric Railway and Motor Company, in 1887, and resigned from the Navy the following year. He did this against the advice of Mr. Sprague, who was of the opinion that he would probably regret leaving the service, though such a regret was subsequently never expressed to the knowledge of his friends. He immediately became very active in the engineering department of the Sprague Railway Company, of which he became chief engineer in 1888. About the first work undertaken was the equipment and operation of some storage-battery cars in Boston, in 1887; shortly after this he was transferred to Richmond, and was in charge of the extremely arduous construction of the first Richmond road. Since that time he has been connected continuously with the corporations which have succeeded the Sprague Electric Railway and Motor Company—that is, the Edison General Electric Company and the General Electric Company. His progress has been one of steady promotion from the beginning; in each new position he developed new qualities, which made his services of greater and greater value. At the time of his death he was the General Sales

Manager of the General Electric Company. The important work of the company in all departments, relating to sales and contracts, passed through his hands. His friends confidently expected that he would become, in the course of time, the chief executive officer of that company, if he elected to remain in it.

As was to be expected from the traditions of his family and his own education, Mr. Greene continued to take a great interest in the Naval service. He was one of the earliest and most active in the formation of the New York Naval Reserve, having risen in this service to the rank of Lieutenant-Commander, his grade at the time of his death. During the Spanish-American War, Mr. Greene served as executive officer of the "Yankee," to which vessel the New York Naval Reserve was assigned, under the command of Captain Brownson. At the close of the war he was appointed Naval Attache on Governor Roosevelt's staff.

Mr. Greene married in June, 1896, Cornelia Chandler, the daughter of Rear-Admiral Ralph Chandler. This marriage occurring only a few years ago, was the termination of a love affair dating back to the time of his leaving the Naval Academy. Their married life was a peculiarly happy one, and their home one to which it was a pleasure to go.

Mr. Greene's work since leaving the old Sprague Motor Company has been more that of an executive than of an engineer. He has, however, always taken a deep interest in electrical engineering questions, and has found time to contribute a number of papers on engineering topics, particularly those connected with naval matters. He has read several papers before the Institute of Naval Architects, and others before the New York Electrical Society and the American Institute of Electrical Engineers. He joined the American Institute of Electrical Engineers in 1893, and was one of its managers at the time of his death. He at all times showed a strong and intelligent interest in the affairs of the engineering fraternity. He has recently served most efficiently as a member of the Committee on National Electrical Code, and was largely responsible for the recent action which has been taken by the fire insurance bodies on the subject of grounding. He was a man of a kind which is, unfortunately, rare—one who combined careful and correct fundamental notions of engineering methods with strong common-sense and a great executive ability. He was not a great engineer, and never professed to be such; but his knowledge of the principles of all engineering matters was very extensive and sound.

The estimation in which he was held by those who knew him is well shown by the following testimonials, which have appeared in print since his death:

"His place in the class of naval cadets at Annapolis, to which he belonged, was so high that he might with confidence have looked forward to the highest preferment in a service to which he was devoted, yet he manfully gave up his chance of being an admiral because he could not see his way to remaining in the Navy without encroaching upon his mother's slender income. In after life, when he had become a successful business man, he always cherished the earliest object of his awakened ambition, though he never openly expressed regret that he had followed what seemed to him to be the path of duty.

"In his business career he climbed the ladder of promotion by self-denying, diligent and honorable service, respecting himself, respecting his employers, and respecting the work which fell to his hands to do. In his intercourse with his official superiors, equals and subordinates, as well as with his customers and the outside world, he was tactful but truthful; reserved but sincere; often cordial but never familiar; prompt, energetic, and accurate in discharging his multitudinous duties.

"To find his attitude on any given question which might arise, one had only to determine what would be the view of a tolerant, impartial and honorable spectator—his zealousness for his company's advancement never betrayed him into sharp practice, he gained universal esteem by his uprightness, and held it by his serenity.

"To this man, at the early age of 35, had come a splendid position in the business world, official recognition of his energy and ability as a volunteer defender of the state and nation, ample means and a charming home, in which was enshrined a woman in every way worthy of him. To-day they seem 'but as yesterday when it has passed, and as a watch in the night.'

"Yet their lives, and more conspicuously his, are full of encouragement and fruits. In these days, when men so often consent to lower their standard of business integrity for the sake of gain, it is well to bear in mind that S. Dana Greene has left his chosen vocation in life at the call of duty and achieved success, and some measure of fame in necessity's field with ideals intact and with untarnished honor."

"Mr. Greene was a strong man, and full of mental and physical energy. He was keenly and continuously interested in everybody and everything. He was a broad and generous-minded man, and seemed to remember people because of something pleasant and wholesome that he knew about them. He remembered things because he saw something in them that could be utilized in the direction of general advancement. Anything new appealed to him instantly, and he was quick to take it up, if it showed

merit. At the same time his judgment and conservatism were of a high order, and he was equally prompt in dropping a useless idea. At the head of a large body of men, he set an example of industry and application to duty that was an incentive to all. No one appealed to him with any problem in vain. With a temperament that was exceedingly even and kind, full of helpfulness and hopefulness, he was one of the most companionable, sympathetic and lovable of men. He occupied a position in the General Electric Company and in the friendship and interest of central-station managers all over the country that was unique, and can never be filled by any other man. To those who have known him for a half-score of years, his death is a personal affliction. Such friends can but be filled with inexpressible grief."

"Lieutenant Greene was one of the most lovable characters I ever met in my life. He was always a stanch and true friend, and while a strict disciplinarian, he always knew how to acquire the love and regard of his associates and of all under his direction. The electrical fraternity has lost in him one of its most prominent members."

"Throughout the electrical field the personal and business popularity of Mr. Greene was remarkable. Uniting with the most perfect integrity in business matters, a cordial manner and a personal charm, which endeared him to his associates, Mr. Greene represented the highest type of the young American man of affairs. His untimely death will cause sincere and widespread regret in all departments of the wide field with which he was so prominently identified. To his business associates, Mr. Greene's death is a great and irreparable loss."

"He bore worthily a name of historic association. Both his father and grandfather rendered to their country distinguished service in the war for the Union. By descent and by nature he came to that nobility that imposes obligation rather than confers privilege, and he was ready and constant in the recognition of the obligation. Graduating at the head of his class at the Naval Academy, he decided against the pursuit of his profession in times of peace, but was prompt to offer his services in time of war, and he gave much time and attention to the development of the State Naval Reserve. His scientific and administrative abilities secured for him a career of great promise in the business in which he was engaged, but his interest never flagged in matters of public concern, for which his training prepared him. Any emergency would surely have found him ready. Cut off in the prime of his young manhood, under circumstances peculiarly distressing, his loss will be widely and sincerely regretted."

C. T. H.

NEW YORK, February 23d, 1900.

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The Education of Electrical Apprentices and Journeymen. By Arthur A. Hamerschlag. Electricity on Board Ship. By S. Dana Greene. No. 1, January, 1899. Storage Batteries and Railway Power Stations. (Illustrated.) By R. McA. Lloyd. No. 2, February, 1899. Propagation of Long Electrical Waves. (Illustrated.) By M. I. Pupin. No. 3, March, 1899. The Limitations of Power Subdivision by Electric Motors in Manufacturing Establishments. A Topical Discussion. No. 4, April, 1899. The Multiple Unit System of Electric Railways. (Illustrated.) By Frank J. Sprague. No. 5, May, 1899. Report of the Committee on Standardization. Symbolic Representation of General Alternating Waves and of Double Frequency Vector Products. (Illustrated.) By C. P. Steinmetz. The Cost of Electricity in Some Typical Buildings in New York City. (Illustrated.) By P. R. Moses. Nos. 6 and 7, June and July, 1899. The Determination of the Wave Form of Alternating Currents without a Contact Maker. (Illustrated.) By Harris J. Ryan. Elements of Design Favorable to Speed Regulation in Plants Driven by Water Power. (Illustrated.) By Allan V. Garratt. The Protection of Secondary Circuits from Fire Risks. By Cary T. Hutchinson. Plea for a Working Standard of Light. By S. Everett Doane. Motor Speed Regulation. By Alton D. Adams. Nos. 8 and 9, August and September, 1899. Electricity in Coal Mining. (Illustrated.) By J. P. Jackson and Frank P. Thompson. Air Gap and Core Distributed. (Illustrated.) By W. E. Goldsborough. Test of a 300-Kilowatt Direct Connected Railway Unit at Different Loads. (Illustrated.) By E. J. Willis. No. 10, October, 1899. Operating Costs of Horse and Electric Delivery Wagons in New York City. (Illustrated.) By Geo. F. Sever and R. A. Fliess. Electric Automobiles. (Illustrated.) By Elmer A. Sperry. Series Arc Lighting from Constant Current Transformers. (Illustrated.) By William Lispenard Robb. Cost of Arc Lighting. (Illustrated.) By H. H. Wait. An American Pacific Cable. (Illustrated.) By George O. Squier. No. 11, November, 1899. The Possibilities of Wireless Telegraphy. (A Topical Discussion.) New York and Chicago, Nov. 22, 1899. No. 12, December, 1899.

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Notes on Electric Traction Under Steam Railway Conditions. By Edward C. Boynton. Notes on Single-Phase Induction Motors. (Illustrated.) By Charles P. Steinmetz. A New Method of Tracing Alternating Current Curves. (Illustrated.) By Fitzhugh Townsend. No. 1, January, 1900. The Evolution of Safe and Accurate Fuse Protective Devices. (Illustrated.) By Joseph Sachs. No. 2, February, 1900.

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### Date of Annual and General Meetings.

At the meeting of the Executive Committee, on February 28th, it was decided that the Annual Business Meeting of the Institute for the election of officers, and reception of the yearly reports, would be held in New York City, on Tuesday, May 15th, being the third Tuesday in the month, as required by the Constitution.

The General Meeting for the reading and discussion of professional papers will begin at Philadelphia, in the afternoon of the following day, Wednesday, May 16th, and continue for two or three days, as may be determined upon hereafter. The meeting will then adjourn to Paris, August 16th, 1900.